UNIVERSITI TEKNIKAL MALAYSIA MELAKA

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STUDY ON AIR DISTRIBUTION ASSOCIATED WITH AIR HANDLING UNIT (DUCT SYSTEM WITH COOLING CASE)

This report submitted in accordance with requirement of the Universiti Teknikal Malaysia Melaka (UTeM) for the Bachelor Degree of Mechanical Engineering Technology (Refrigeration and Air Conditioning system) (Hons.)

by

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FACULTY OF ENGINEERING TECHNOLOGY

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BORANG PENGESAHAN STATUS LAPORAN PROJEK SARJANA MUDA

TAJUK: **STUDY ON AIR DISTRIBUTION ASSOCIATED WITH AIR HANDLING UNIT (DUCT SYTEM WITH COOLING CASE)**

SESI PENGAJIAN: **2016/17 Semester 1**

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APPROVAL

This report is submitted to the Faculty of Engineering Technology of UTeM as a partial fulfillment of the requirements for the degree of Bachelor of Engineering Technology (Refrigeration and Air Conditioning system) (Hons.). The member of the supervisory is as follow:

……………………………………

(Project Supervisor)

ABSTRACT

Nowadays, human comfort and thermal comfort in buildings is a very major concern in the use of air conditioning systems. We usually encounter in which human comfort and heat not be achieved on a number of factors. This is likely because the cooling air distribution system from AHU to the occupied zone, fail to control moisture and leaks at the design air volume flow. Therefore, this study aims to determine the correct location and orientation of the branches required in the duct AHU related systems using Hydronic Radiant Cooling (HRC) System. Using hydronic radiant cooling (HRC) system we are able to minimize risks to humans and the environment from dangerous substances contained in other coolants. The study was conducted using three types of studies for each branch and orientation, of the use of water, water with ice, and water with ice and salt. The results of three studies, the temperature at the first branch using water with ice and salt most cold compared with other branches at the top of 20.2°C. However, the temperature of the third branches is more suitable to achieve thermal comfort in Malaysia of 23.2 ° C within the range of thermal comfort of 23°C to 26°C. In conclusion, the results of this study showed that the temperature in the third branch more suitable for residents in Malaysia. While the appropriate orientation in the system is at the top because the air circulation at the top is better than bottom, left and right to reach the thermal comfort in Malaysia.

ABSTRAK

Pada masa kini, keselesaan manusia dan keselesaan haba dalam bangunan adalah sangat diambil berat dalam penggunaan sistem penyaman udara. Kita biasanya dapat melihat di mana keselesaan manusia dan haba tidak dapat dicapai atas beberapa faktor. Hal ini berkemungkinan kerana, sistem pengedaran udara penyejukan dari AHU kepada zon yang diduduki, kegagalan kawalan kelembapan dan bocor pada reka bentuk aliran isi padu udara. Oleh itu, kajian ini dijalankan bertujuan untuk mengetahui lokasi yang betul dan orientasi cawangan yang diperlukan pada salur sistem berkaitan AHU dengan menggunakan Hydronic sistem penyejukan berseri. Dengan menggunakan hydronic sistem penyejukan berseri kita mampu untuk mengurangkan risiko terhadap manusia dan alam sekitar daripada bahan-bahan yang berbahaya yang terdapat pada bahan penyejuk lain. Hal ini kerana hydronic sistem penyejukan berseri menggunakan air. Kajian ini dijalankan dengan menggunakan tiga jenis kajian bagi setiap cawangan dan orientasi iaitu, menggunakan air, air dengan ais, dan air dengan ais dan garam. Hasil dari 3 kajian, suhu pada cawangan pertama yang menggunakan air dengan ais dan garam paling sejuk berbanding dengan cawangan lain iaitu pada bahagian top 20.2°C. Namun begitu, suhu pada cawangan tiga lebih sesuai untuk mencapai keselesaan haba di Malaysia iaitu 23.2°C berada dalam julat keselesaan haba 23°C hingga 26°C. Secara kesimpulannya, hasil kajian ini menunjukkan bahawa suhu pada cawangan ketiga lebih sesuai untuk penghuni di Malaysia. Manakala orientation yang sesuai dalam sistem yang dibuat ialah pada bahagian atas kerana peredaran udara pada bahagian atas lebih baik berbanding bahagian bawah, kiri dan kanan untuk mencapai keselesaan haba di Malaysia.

DEDICATIONS

To my beloved parents

MAT HUSSIN BIN IDRIS

SYARIFAH BINTI MOHAMAD

Special dedicated to my supervisor

PN NOOR SAFFRENA BINTI HAMDAN

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In the name of Allah, most gracious, most merciful. All thanks to the almighty for his will, the study can be completed successfully. Appreciation and gratitude addressed to Ms. Noor Saffreena Bint Hamdan, as a supervisor of this project has been a lot of help and guidance, attention, encouragement and advice in conducting this study.

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CHAPTER 1
INTRODUCTION

In this chapter, to most important subtitle topic involve are background, problem statement, objectives, and scope of study.

1.0 Background

Air-conditioning is the process of changing the nature of air temperature and humidity mainly to more comfortable conditions. It intends to distribute air to occupied zones such as vehicles and buildings to improve thermal comfort and indoor air quality. The process of heat transfer in the refrigeration system requires four components, namely compressor, condenser, expansion valve, and evaporator. However, air handling unit (AHU) is also used for cooling or heating purpose. Air Handling Unit (AHU) is a tool used to regulate and circulate air as part of a heating, ventilating and air conditioning system. The air handling unit (AHU) usually is a large metal box containing the blower, heating or cooling element, chamber, sound attenuator and dampers. Air handling unit is usually connected to the distribution and ventilation system such as air ducts that circulate cold or hot air through the building and return it back to the AHU.

Due to hot weather in Malaysia, air conditioning system is taken more care and attention to provide comfort to occupants in buildings and vehicles .Cooling of air is an idea for dissipating heat. It works by using a cool object has a larger surface area exposed to flow of natural air over the surface. Ducting system is very important for the distribution of air in the building. Physical suitability for concern is that the distribution of the air force in accordance with the situation.

1.1 Problem Statement

Discomfort problems are commonly referred to irregularity of air distribution system (the branches in duct system). However branch carries the cooling air from AHU to occupied zones. Leaking of air temperature, failure to control humidity, and leaking of air volume flow rate design are the most limitation. The current project is dealing with air distribution problems via presenting a study on the proper location and orientation of the required branches associated with AHU using Hydronic radiant cooling system. Moreover the air flow rate design is consider as well.

1.2 Objectives

In this study, some target have been set to ensure that the current study is not stray away from the original target when investigations are conducted. The most important objective of the current study are:

i. To study the possibilities of using Hydronic Radiant Cooling (HRC) as an alternative cooling system in Malaysia as a cooling source.

ii. To develop a prototype of an Air Handling Unit to apply for Hydronic Radiant Cooling in achieving the desired temperature in the appropriate orientation.

1.3 Scope of Study

The water temperature is measure in water container to get a considered air temperature in AHU. An enclosed space results in less air travellers, the flow of air to each room requires a suitable process to reduce the quantity of air that is not comfortable with how to study and design the ducting holes with distance and appropriate use of materials. The design of the AHU and duct are carried out in Fabrication laboratory FTK UTeM.

CHAPTER 2
LITERATURE REVIEW

In this chapter, to most important subtitle topic involve are introduction, air handling unit, air distribution, hydronic and cooling case.

2.0 Introduction

This Chapter is continuously carry to study past and current research work. Some very important issues and data have to be studied, reviewed, determined and applied for the project which is "Study on Air Distribution Associated with Air Handling Unit (Duct System with Cooling Case)". There are previous researches on air distribution, air handling unit, hydronic system and cooling case. In addition, in this chapter it will be include about the theory of air conditioning system.

2.1 Air Handling Unit

Air handling unit is shown in Figure 2.1. Air Handling Unit is a device used in order to regulate and circulate air as part of a heating, ventilating, and air-conditioning (HVAC) system. It contains blower, heating or cooling elements, filter racks or chambers, sound attenuators, and dampers. A ductwork usually is connected as the ventilation system in which distributes the conditioned air through the building and returns it to the AHU. Usually, AHU usage is able to cut the cost of the operation.

According to (Dusan Licina, Chandra Sekhar, (2012) This higher energy use is due to many factors including provision of large amounts of 100% outside air, continuous operation, requirement for stringent internal parameters, high fan energy, etc. At the same time, imbalance seems to exist between the current cost of water and the actual value of that water to the society and environment. Even purified and distributed over long distances, water is available for such a low cost that it usually consumed irrationally.

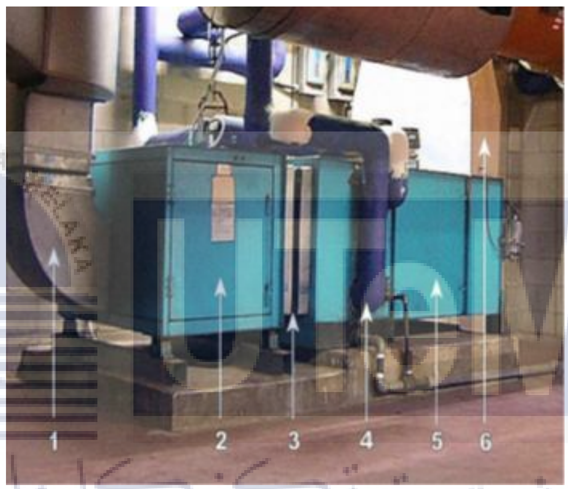


Figure 2.1: Air Handling Unit

2.1.1 Blower/Fan

Liquid flow of gas such as air created by the fan . The fan consists of a set of rotating blades and blade acting on the fluid . Fan blades supported by an electric motor . In addition, another power source such as a hydraulic motor and an internal combustion engine can also be used. Fans are of two types , namely Axial flow fan and centrifugal fan.

2.1.1.1 Axial Flow Fan

Tangential direction with swirling air created by the rotation of the impeller blades is the axial flow fan. Figure 2.2 shows the movement of axial fan air flow. Kinetic energy to static pressure (SP) is a very small increase and potential energy , while the flow velocity is increased by a yielding rotation velocity pressure (VP) . In commercial applications, axial fans are commonly found as it moves large volumes of low pressure air. Twin City Fan Companies, Ltd (2000).

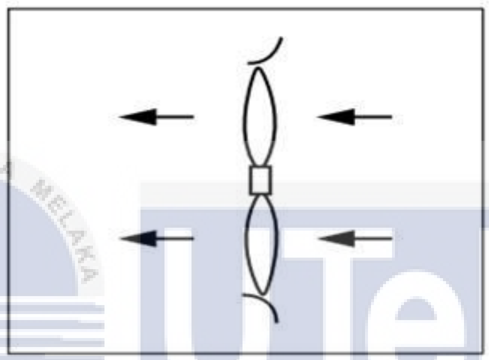


Figure 2.2: Air Flow Movement for Axial Fan (Twin City Fan Companies, Ltd 2000)

Propeller fans, tube axial fan, and Vane Axial Fan are three main types of axial flow fan in the industry. The tube axial fan, fan efficiency up to 65% and the fan inside a cylindrical housing. Beside that for propeller fan speed is rotate slowly and moderate temperature, it change the large airflow to small static pressure and efficiency is low approximately 50% or less.

Furthermore for the vane axial fan it like tube axial but have additional of guide vanes because to improve the efficiency of the fan. The static pressure with is high, if the static pressure high, the efficiency of fan is very good. Figure 2.3 shown the picture of the as Propeller fan, Tube axial fan and Vane axial fan. Bureau Energy Efficiency Companies (2002).

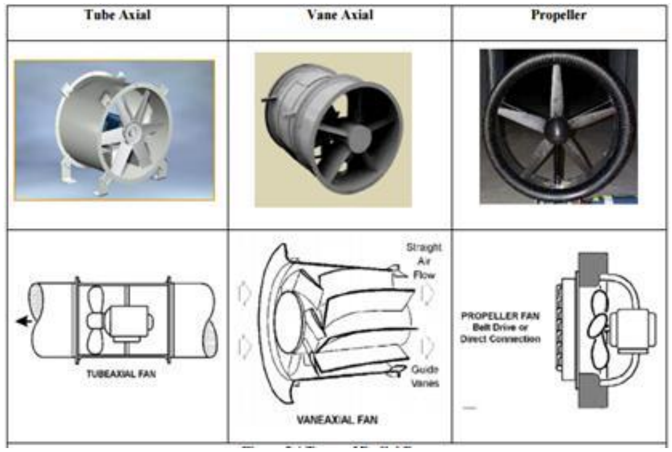


Figure 2.3: Type of Axial Fan (Bureau Energy Efficiency Companies (2002).

The table 2.1 show the characteristic and application of the type of Axial Flow Fan. Bureau Energy Efficiency Fan Companies (2002).

Table 2.1: Characteristic of Axial Flow Fan (Bureau Energy Efficiency Fan Companies, 2002)

Type	Characteristic
Propeller Fan	i. Maximum efficiency at lower pressure ii. It develop for low pressure and high rate air flow iii. Comparatively noisy iv. Inexpensive
Tube Axial Fan	i. Fan efficiency up to 65% ii. Used belt drives to rotate the fan iii. Generates moderate airflow noise iv. High pressure and efficiencies than propeller fan
Vane Axial Fan	i. The efficiency up to 85% are achievable ii. The airflow profile is uniform iii. Highly efficient if equipped with the blade build

		with small clearance
	iv.	The vane axial essentially a tube axial fan to straighten airflow with outlet vanes

2.1.1.2 Centrifugal Fan

Centrifugal fan is a some device for moving air or gases. The function of centrifugal fan is to rotting impeller to move the air first radially outward toward by centrifugal action. The air thru blade, after that when the blade is rotate the air flow it gain kinetic energy and then the kinetic energy convert to static pressure and increase the pressure of the air which in turn moves the against the resistance caused by duct, damper and other. Figure 2.4 shown the air flow movement of centrifugal fan.

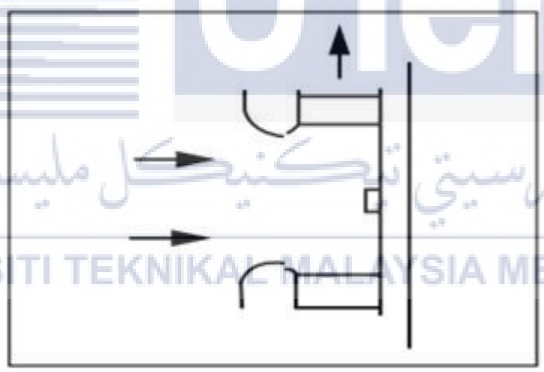


Figure 2.4: Air Flow Movement of Centrifugal Fan (Twin City Fan Companies, Ltd 2000)

The centrifugal fan can divided into three type such as Paddle Blade (Radial Blade), Forward-Curve Blade, and Backward-Curve Blade, Bureau Energy Efficiency Fan Companies (2002). The Figure 2.5 shown the picture of the major type of centrifugal fan.

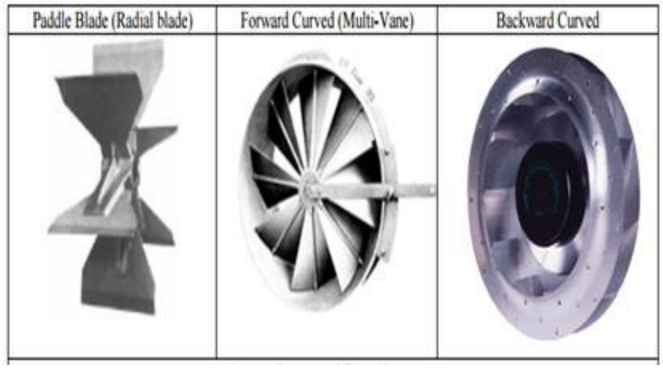


Figure 2.5: Type of Centrifugal Fan (Bureau Energy Efficiency Fan Companies (2002)

The radial blade is industrial workhorses because the static pressure is high, the special about this fan is it can handle heavily contaminated airstream. On top of that the design of radial fan is very simple and it suitable for high temperature and have medium blade speeds. That is not has the blade curve. Figure 2.6 show the blade of radial blade.

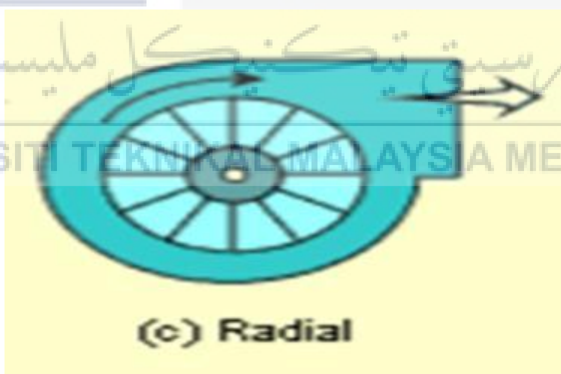


Figure 2.6: Radial Blade Fan

The Forward-curve the blade direction is same to the rotation of the fan. Basically the application is required low to medium air volume at low pressure. The Figure 2.7 show the Forward-curve blade fan.

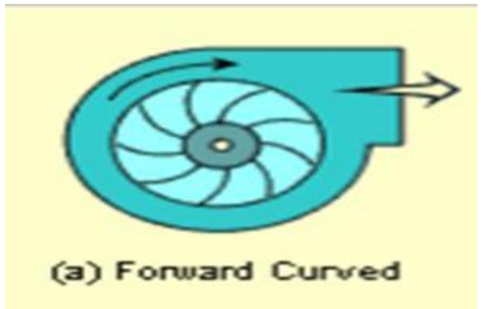


Figure 2.7: Forward-curve blade fan

Besides that, for the Backward-curve fan is the orientation of the blade angle is low of impingement with the airstream. The blade and rotational of the blade is different side. Figure 2.8 show the Backward-Inclined fan.

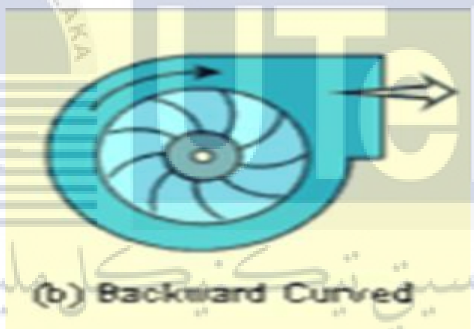


Figure 2.8: Backward-Inclined fan

2.1.2 Heating or Cooling Coil

According to Liang Xia, et.al. (2010), the installation of air conditioning, air cooling coil is an important component. If the surface temperature of an air conditioning coil is lower than the air temperature, the cooling coil will be operated under wet conditions. This is commonly seen in the installation of air conditioning in hot and humid climates.

X. J. Zhang et.al. (2010) state that, for humidity control, cooling coil adjust the cold water temperature according to the load dehumidification or latent load. While for the temperature control, coil cooling adjust the mass flow rate of cold water in the cooling load reasonable.

2.1.3 Ducting

Building efficiency improvements driven by higher energy standard. To build efficiency as a result of changes to the heating or cooling system, an increase in construction materials, building design or code. This approach ignores the way in which air is dispersed into individual rooms or in the building, namely the ducting system.

Therefore, this opens the possibility of significant energy savings by making ductwork system is lighter and better insulation while ensuring cost effectiveness (Anthony Fontanini, et.al, 2011). A ducts system is also called ductwork. It is used in heating, ventilation and air conditioning (HVAC) aims to deliver and remove air Among the required air flow is like , the supply air , return air and exhaust air . The duct also submit regular air ventilation as part of the air supply. Therefore, the airway is one way to ensure indoor air quality and thermal comfort can be accepted. Duct can be made with some kind of material such as Galvanized steel, Aluminium, Polyurethane and phenolic insulation panel (pre-insulated air ducts), Fiberglass duct board, Flexible Ducting, Fabric Ducting and Waterproofing. Figure 2.9 show the duct system of Air Handling Unit.

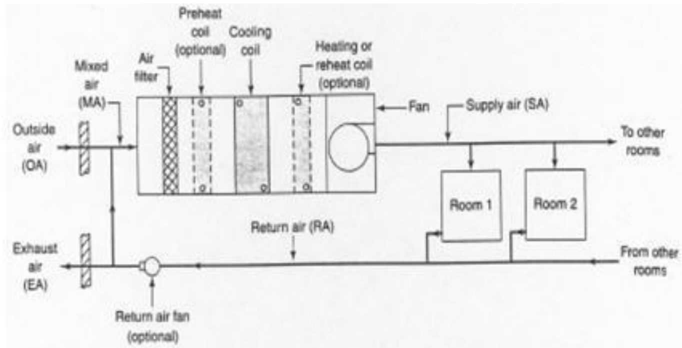


Figure 2.9: Duct System of Air Handling Unit

2.2 Air Distribution

Under floor air distribution (UFAD) is a mechanical ventilation strategy in which the conditioned air is delivered to the zone from a pressurized plenum through floor mounted diffusers. UFAD has the potential to increase flexibility to change office layout and to reduce the floor-to-floor height. UFAD systems may also provide improved indoor air quality and thermal comfort as well as energy savings.(Stefano, et.al, 2010).

2.3 Hydronics

Hydronic is where the use of water or liquid heat transfer medium. Among them are, glycol is used as the heat transfer in heating and cooling the system. In history, large-scale commercial buildings such as high-rise buildings and campus facilities, hydronics system including both chilled and heated water coils, to provide both heating and air-conditioning. Chillers and cooling towers are used separately or together as means to provide water cooling, while boilers heat water. The basic type of hydronic system is steam or hot water and chilled water.

Hydronic system are classified in five ways namely, Flow generation (forced flow or gravity flow),Temperature (low, medium, and high), Pressurization (low, medium, and high), Piping arrangement, and Pumping arrangement. Besides, hydronic system also may be divided into several general piping arrangement categories such as Single or one-pipe, Two pipe steam (direct return or reverse return), Three pipe, Four pipe, and Series loop. Figure 2.10 is one of hydronic snow melting system.

Figure 2.10: Snow Melting hydronic

2.3.1 Hydronic Radiant Cooling (HRC) system

In study by A.S.Binghoot and Z.A.Zainal (2012) reported that in terms of energy consumption, hydronic radiant cooling system (HRC) into alternative methods to improve the performance of conventional air conditioning systems. In addition, the RHC also aims to improve indoor air quality. However, any areas using cooling coils with air blower mainly for conventional air conditioning system, it requires refrigeration capacity is much higher for cooling a higher number of hot and humid air that it receives. Hydronic radiant cooling is an air conditioning system that is considered different because of the fresh air is high. Hydronic radiant cooling system (HRC) using cold water as a cooling medium through cooper tubes embedded in an aluminum panel.

Therefore, in hydronic air chilled ceilings, internal moisture behavior and the effect on condensation is an important consideration. This causes the ceiling to cool the dehumidified air ventilation has advantages with regard to thermal comfort, energy savings and the absence of condensation.

2.4 Cooling Case

Hamdan b. Ali et al. (1989) states that as HVAC stands for Heating, Ventilating and Air Conditioning. The goal is to provide thermal comfort and indoor air quality that can be accepted by each individual. HVAC system design is the sub discipline of mechanical engineering based on the principles of thermodynamics, heat transfer and fluid mechanics. However, in this system, cooling is the primary objective. To ensure that this system can be received by an individual with a good cooling system must be at an appropriate level. Cooling is the process whereby the occurrence of heat transfers from one place to another without danger to life and the environment. There are four essential components required in heat transfer, namely, condensation, compression, evaporation and metering devices.

Four of these components have its own function to produce cooling. Compressor works to pump refrigerant through the system. Condenser also works on the cooling system as a remover of heat from the refrigerant vapor. While the evaporator is a device or component that is located between the low pressure metering side and compressor. The refrigerant is the fluid used to remove heat from the cooling system. Each liquid has a boiling point close to the freezing point of water and can be used as a coolant. However, the coolant that good is not necessarily a low boiling point temperature. The refrigerant that good should have features like , does not corrode the components , nontoxic, and not explosive . Besides other qualities that should be taken into account in conditioning ingredients such as volume density, the effect of coolant on heat and temperature , pressure , chemical properties and physical coolant. Table 2.2 shows the properties of a good cooling.

Table 2.2: Properties of a good cooling (Hamdan b. Ali, et.al, 1989).

Properties	Characteristic
The effect of heat on temperature	i. The latent heat of the refrigerant vapour must be high ii. Coolant temperature must be lower than the temperature that exist in any part of the system
Volume density of the refrigerant	i. The density of the refrigerant must be high ii. Steam volume must be as small as possible
The impact of stress on material conditioning	i. Effects of air pressure on the high and low as possible small . ii. When the condenser pressure is low, the light can be used and leakage can be avoided
Chemical properties	i. Resistant to temperature and pressure operating system and does not change the nature ii. Not flammable or explosive iii. No toxic
The properties of the coolant	i. No danger when reacted with oil despite the presence of moisture ii. Can be soluble in oil lubrication so effective iii. Have high resistance to electric
The coolant	i. The first group (the safest in use) ii. Group second (half-flammable and poisonous) iii. Group third (flammable)

In addition, the coolant can also be used such as water, calcium chloride, sodium chloride , glycol ethylene and propylene , methanol (methyl alcohol) and glycerin . This is a type of coolant liquid from the cooling system that absorbs heat when cooled by the evaporator. Water is used as a refrigerant commonly used in air conditioning systems and industrial large which requires temperatures in excess of freezing temperatures.

CHAPTER 3

METHODOLOGY

The methodology of this project can be archived with design, fabrication and experiment works.

3.0 Introduction

This Chapter will be explaining more detail about the method or finding that relate with this project. Besides, it also will be explain about material, subjects or equipment that is used in this project. The major steps that have been used in this project are Design, Fabrication and experiment work.

Figure 3.1: Major Step in Methodology

3.1 Design

Creating idea for several desing is call design concept or conceptual desing. As for this project, the concept design based on dimension, shape, and drawing of the prototype for this project. The prototype in this project consists of 2 main part that are an Air handling unit and ductwork covered by the acrylic. Air handling unit is designed to created cooling capacity and evaluate thermal comfort level. The dimension of air handling units (AHU) and ductwork are the same size of 25.5m x 19.0m. While the size of the fan casing were 34.3m x 32.0m. The fan is placed in front of the AHU intended to generate water flow to cooper tube for the cooling process. In addition, the use of a fan to cooper tube is 15.0m while the distance from cooper tube into the channel of ductwork also is 5m. Channel of ductwork punched in 4 parts, top, bottom, and two on the side. On each side, three channels will be drilled. Figure 3.2 show the schematic diagram of the prototype.

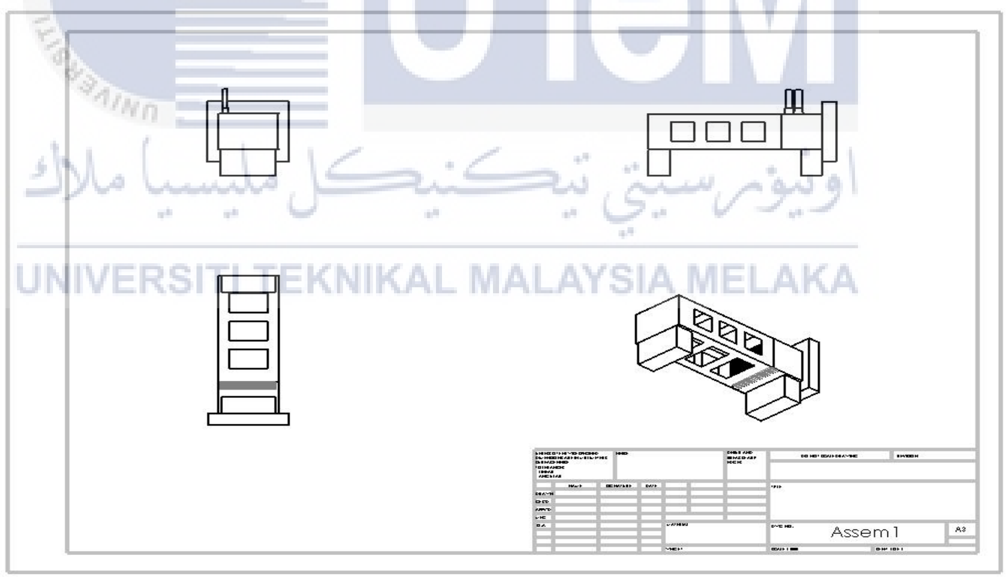


Figure 3.2: Schematic diagram of the prototype.

Figure 3.3 : The actual project

3.2 Fabrication

First and the foremast, this method is used to collect all information about this project. All the information state that in fabrication is material selection. The selection of material that we use most important because the material use can be effect to the result of this project.

3.2.1 Materials and Equipment selection

The main material that we use for construction of prototype are as the following:

i. Acrylic

Use the acrylic is designed AHU and ductwork.

Figure 3.4: Acrylic

ii. Radiator Fan

Use to force outside air enter the Air Handling Unit. It is capable to generate a large air flow and suitable for application requiring ventilation and cooling when the entire space inside the device must be cooled.

Figure 3.5: Radiator Fan

iii. Cooling coil

Chilled water is allowed to flow inside cooling coil which are attached at the acrylic of AHU.

Figure 3.6: Cooling coil

iv. Pump

A small pump is used to drive the water from the tank into cooper tube, water then circulate in this system to complete the cooled process.

Figure 3.7: Pump

v. Cooling elements

Cooling elements used in this experiment composed of water, ice cube, and salt. Salt is used to increase boling point.

vi. container

To store chilled water.

The equipment use during the experimental work.

i. Thermometer

To determine the parameters of cold temperature in container and the temperature out in duct at each location

Figure 3.8: Dial thermometer

ii. Pitot traverse

To measure the amount of air and air velocity for fan that went into space ducting for all channel.

Figure 3.9: Pitot traverse

3.3 Experimental Works

In this study, two experiment work are conducted. The first experiment will be conducted with determine the water temperature in container. The second experiment, a suitable location for proper orientation**.**

3.3.1 First Experiment (water temperature in container)

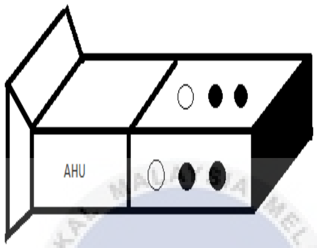
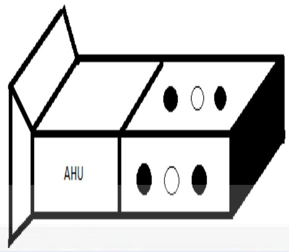
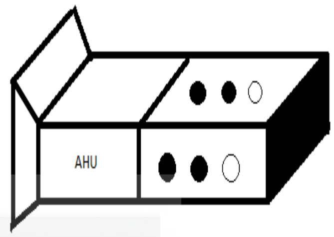
To archive the first objective, have 3 case of experiment work. The first case is pouring water into the container until it reached the maximum level of the indicator and switch on the pump to circulate the water into cooper tube. Then, the temperature of the water is measured using thermometer. Afterward, ice cube is added into the container as a cooling source and wait for 10 minutes to ensure thermal equilibrium occurs between the ice cube and water. After 10 minutes, the temperature of water inside the container is measured. Subsequently, salt solution is added into the container to lower the temperature, so that it can be varied for cooling temperature. Wait for 10 minutes for every increment of the amount of salt as a solution added into the container to ensure thermal equilibrium occurs between the water, ice and salt. Once thermal comfort temperature standard for Malaysia is archived between the range 23˚C to 26˚C.

3.3.2 second experiment (location and orientation of the branch)

The air velocity and temperature is most important in this experiment to archive the objective. To archive the second objective, also have three experimental works was carried out on the branch. The experiment conduct with branch 2 and 3 will be closed.

For the second experiment, branch 1 and 3 are close and the last one is close branch 1 and 2 for open branch 3 only. From this experiment, the temperature at the branch where more appropriate and archive thermal comfort.

Table 3.1: show the schematic of the experiment for branch.

Case 1	Case2	Case3
		

CHAPTER 4

RESULT & DISCUSSION

The result of this project can be archived with data collection and data analysis.

4.0 Introduction

This chapter discuss about the effectiveness of the system depending on the chapter discusses the effectiveness of the system depends on the experiment carried out in the previous chapter. Effectiveness of the system will focus on the resulting temperature and orientation on the appropriate channel. Discussion of the experimental results will also be included in this chapter .

4.1 Analysis Temperature in Container

Before the recruitment process temperature in the channel is run, test the temperature in the container should be carried out to determine whether the water temperature in the container can be achieved or not. It aims to determine whether hydronic cooling system is able to produce the lowest temperature to cool areas that receive much higher heat and humidity. Thus, Table 4.1 shows the results of the temperature in containers that have been carried out. The amount of water used is the same, but the weight of ice and salt capable of generating different temperatures.

However, the resulting temperature change on the ice and salt placed in the container. Here we can see, the use of ice to produce 1kg temperature 9 ° C, but after the ice plus up to 3kg to 5kg temperature of 0 ° C. This is because, in the use of 3kg of ice, the temperature in the container has reached the maximum ice. However, after this salt can be found in the container, the temperature dropped to -8 ° C only using 0.5kg of salt. To ensure that this research is successful, the lowest temperature to be achieved, namely to increase the amount of salt as much as 1kg and 1.5kg The resulting temperature is the same, namely -4 ° C. This shows that in this study, the lowest temperature can be achieved in the former is -4 ° C.

Table 4.1 : Temperature in container when using water, ice and salt.

WATER (liter)	ICE (kg)	SALT (kg)	TEMPERATURE (°C)
2	1	-	9
2	2	-	1
2	3	-	0
2	4	-	0
2	5	-	0
2	5	0.5	-8
2	5	1	-4
2	5	1.5	-4

4.2 Analysis of Temperature

Temperature analysis was based on the analysis of temperature by time for all orientation, and temperature by channel.

4.2.1 Analysis of Temperature by times

Through these experiments, three cases were carried to determine the water temperature by water, water and ice, and water, ice and salt every 10 minutes.

Table 4.2 : Temperature of Water, Water and Ice, and Water, Ice and Salt

	TIME (minutes)	CHANNEL 1				CHANNEL 2				CHANNEL 3			
		TOP	BOTTOM	LEFT	RIGHT	TOP	BOTTOM	LEFT	RIGHT	TOP	BOTTOM	LEFT	RIGHT
WATER	10	27.5	28	28	28.8	27.8	28.5	28.2	29	28	28.8	28.5	29
	20	27.5	28	28	28.8	27.8	28.5	28.2	29	28	28.8	28.5	29
	30	27.5	28	28	28.8	27.8	28.5	28.2	29	28	28.8	28.5	29
	40	27.5	28	28	28.8	27.8	28.5	28.2	29	28	28.8	28.5	29
	50	27.5	28	28	28.8	27.8	28.5	28.2	29	28	28.8	28.5	29
	60	27.5	28	28	28.8	27.8	28.5	28.2	29	28	28.8	28.5	29
AVERAGE (°C)		27.5	28	28	28.8	27.8	28.5	28.2	29	28	28.8	28.5	29
WATER + ICE	10	18	18.8	18.5	18.8	19	20	19.8	20	21	21.5	21.8	21.8
	20	19	22	20.5	22	20.5	23	21.8	22.5	22	23.5	22.5	23
	30	23.8	23.8	23.8	24	24	24.5	24.5	24.5	24.8	24.8	24.8	24.8
	40	24.2	24.5	24.5	24.8	24.8	25	24.8	25	25	25.5	25	25.5
	50	25	25	25	25.5	25.2	25.5	25.5	25.8	25.5	25.8	25.8	26
	60	25	25	25	25.5	25.5	25.5	25.5	25.8	25.5	25.8	25.8	26
AVERAGE (°C)		22.5	23.2	22.9	23.4	23.2	23.9	23.7	23.9	24.0	24.5	24.3	24.5
WATER + ICE + SALT	10	17	18	17.5	19	18.5	19.8	19	19.8	20	21	20.5	20.5
	20	18	19.5	19	19.8	20	21	20.5	21	20.8	22	21	21.5
	30	19.5	20.5	21.5	22.5	23	23.5	24	23	23.5	23.5	24.5	23.8
	40	21.5	21.5	22.5	23.5	24	24.8	24.5	24	24.8	25	24.8	24.5
	50	22	23	23	24	24.8	25	25	24.5	25	25.5	25.5	25
	60	23	23.5	24	24.5	25	25	25	25	25	25.5	25.5	25.5
AVERAGE (°C)		20.2	21.0	21.3	22.2	22.6	23.2	23.0	22.9	23.2	23.8	23.6	23.5

4.2.1.1 Temperature for using water only

Figure 4.1, 4.2, 4.3 and 4.4 shows the temperature at which the position of the different channels using just water. Not too significant temperature changes as the water temperature in the container is almost the same as the temperature of the room used for this experiment, although the time spent to retrieve data is different.

Figure 4.1 shows the temperature at the top of the three channels. The temperature difference between the three channels is between 0.3°C to 0.5°C. But do not change the temperature of the three channels from the first minute to minute 60.

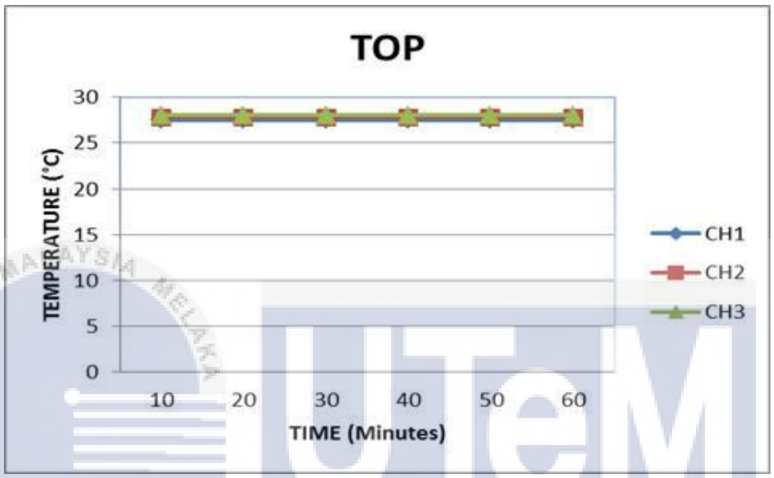


Figure 4.1 : Temperature by times for top using water

Guided figure 4.2, experiment data show the number of temperature between the three channels are not too significant. Changes in temperature at the bottom is the same as the top of the three channels of 0.3°C to 0.5°C.

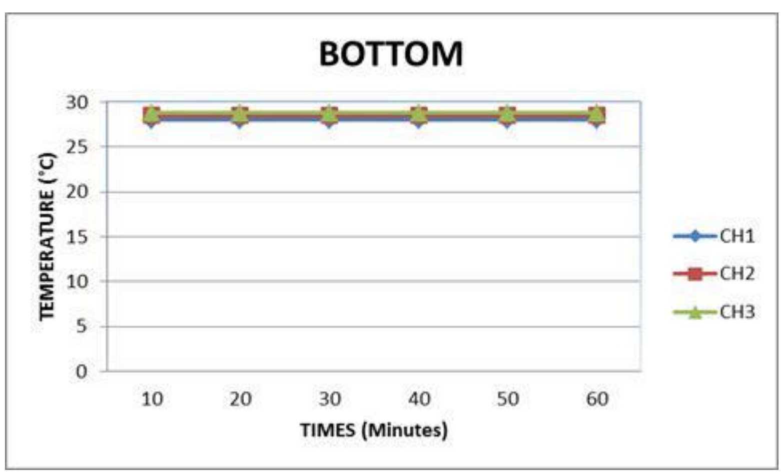


Figure 4.2 : Temperature by times for bottom using water

Figure 4.3 is an analysis of temperature data to the left. It can be seen that the temperature difference between channels is not too significant. This is so because, the water temperature is almost the same as room temperature. However, there is a change between the channel temperature of 0.2°C to 0.3°C.

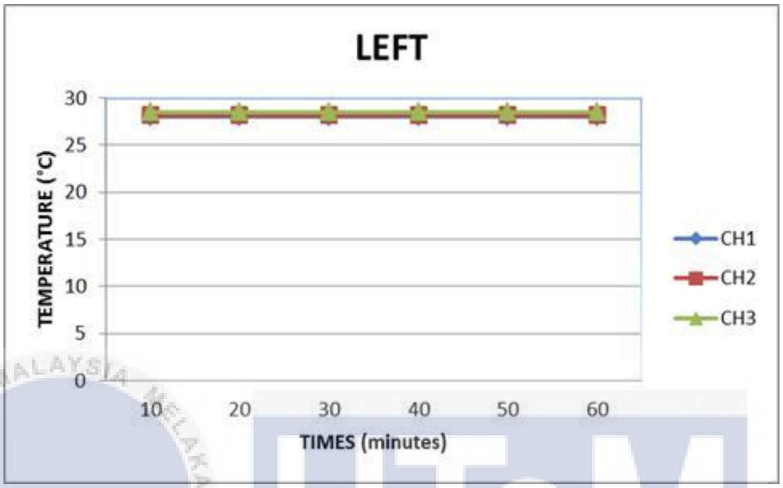


Figure 4.3 : Temperature by times for left using water

Refer to Figure 4.4, it can be seen that there is no change in temperature occurs between the time for all three channels. However, there is a temperature change between channels 2 and 3 of 0.5°C.

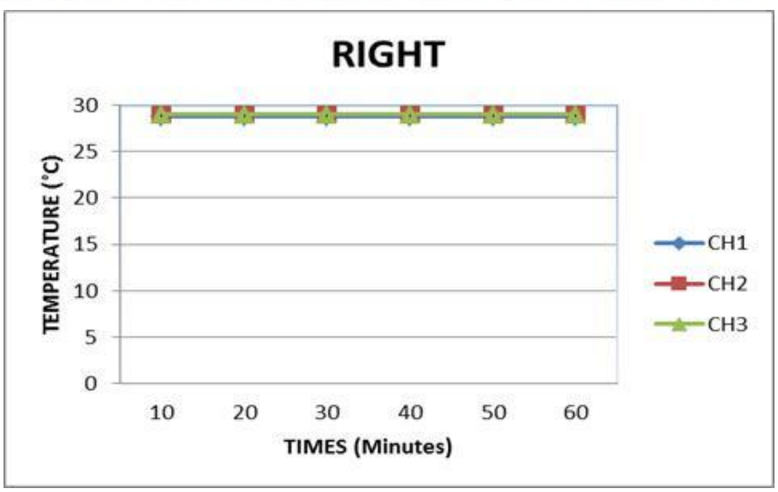


Figure 4.4 : Temperature by times for right using water

4.2.1.2 Temperature for using water and ice

Experimental measurement for water and ice, using the same method as the temperature of the water taken after 10 minutes for each of the readings for each channel until 60 minutes. however it can be seen that the temperature change is increasing for all three channels. This is because in the first 10 minutes the temperature in the container is still at a low temperature. after 10 minutes elapsed, the temperature within the container will rise as more ice melts. thus the resulting temperature rise on each channel. however, the temperature at the top is lower than the bottom, right and left for all three channels. Figure 4.5, 4.6, 4.7 and 4.8 shows the resulting temperature difference for each channel at different orientation.

Figure 4.5 is an experiment carried out in the temperature of the water added to the ice. In this figure, we can see the temperature on channel 1 in the first 10 minutes was the lowest compared to other channels. But at 50 and 60 minutes to the temperature already at the same level on each channel.

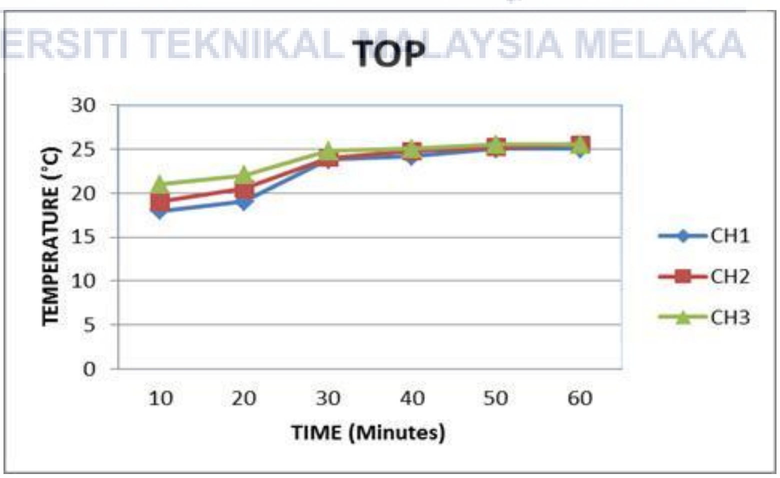


Figure 4.5 : Temperature by times for top using water and ice

Based on the figure 4.6, the lowest temperature in the first 10 minutes in the bottom of the channel 1. The highest temperature also on channel 3. This is because a channel 3 further away from the cooling coil. Temperature change is seen to increase at minute 20 to 60. This is because the ice in the container and the liquid temperature is rising.

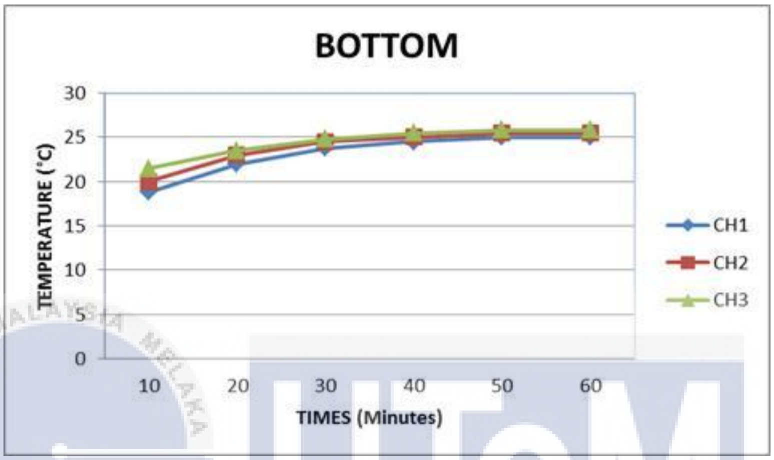


Figure 4.6 : Temperature by times for bottom using water and ice

Refer to Figure 4.7, the change in temperature on the left in the first 10 minutes as well as at the top and bottom. The lowest temperature can be seen on channel 1 and the highest on channel 3.

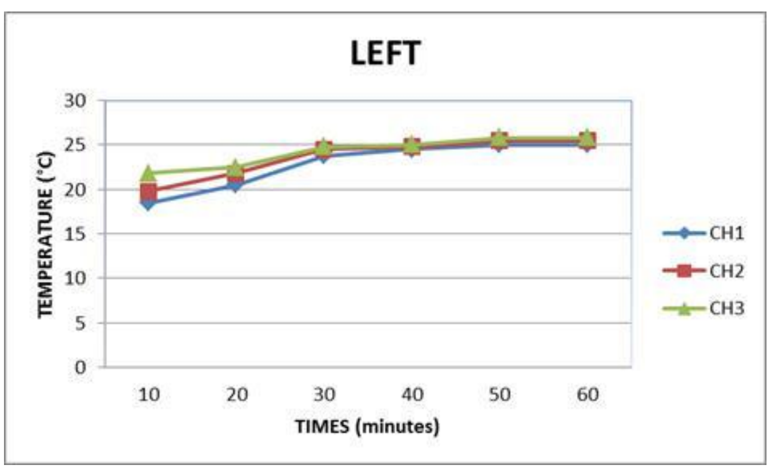


Figure 4.7 : Temperature by times for left using water and ice

Figure 4.8 also is at the right temperature for each channel. Just like elsewhere, the lowest temperature in the first minute is on channel 1 and the highest on channel 3. Temperature rise in the next minute to minute 60.

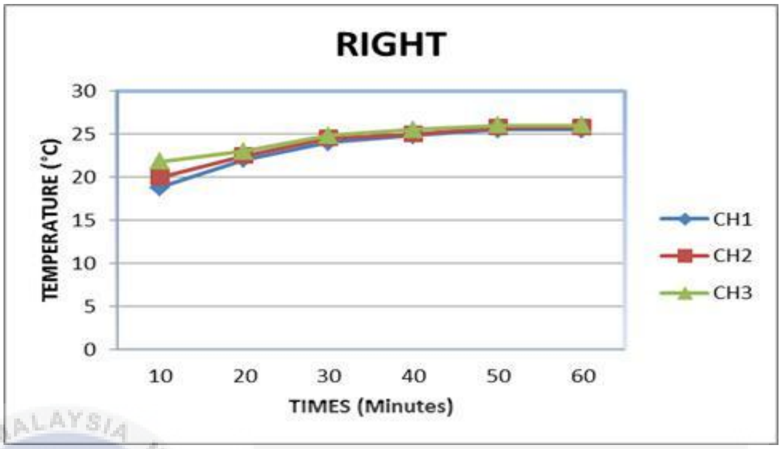


Figure 4.8 : Temperature by times for right using water and ice

4.2.1.3 Temperature for using water, ice and salt

Figure 4.9, 4.10, 4.11 and 4.12 shows a graph of the water temperature, ice and salt. the experiment carried out is the same as the water and add ice. The resulting temperature is lower than the case because with the addition of salt in the container, the lower the temperature, the temperature resulting in lower per channel. However, with the change of time taken, the temperature in each channel is also growing due to the melting of ice in the container. The low temperature at the top is the same as the two previous case are ongoing.

Figure 4.9 is a top temperature taken during the experiment for the water temperature in the container was added with ice and salt. Can be seen more significant changes in temperature between the three channels. The lowest temperature on channel 1 and channel 3. The high temperature changes significantly for channel 1, 2 and 3 in the first 10 minutes. But on 20 minutes the temperature on channel 2 and 3 are almost the same compared with channel 1.

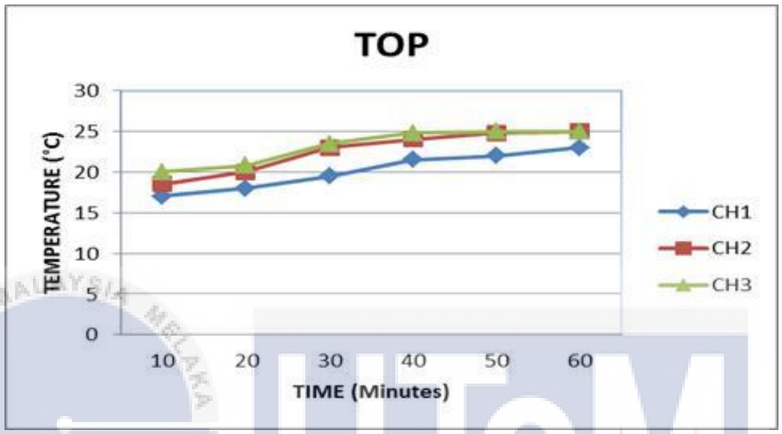


Figure 4.9 : Temperature by times for top using water, ice and salt

Based on the figure 4.10, the temperature at the bottom as the top. Lower the temperature on channel 1 and channel high on 3. This is because, channel 1 is closer to the cooling coil. From the first minute to minute 60 to see the most low-temperature channel 1.

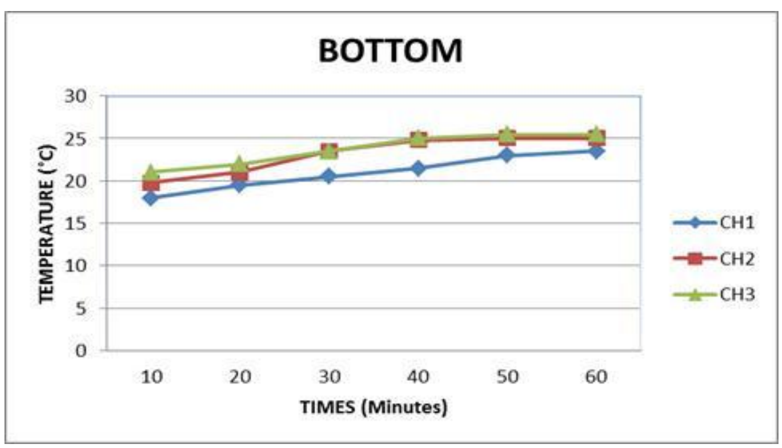


Figure 4.10: Temperature by times for bottom using water, ice and salt

Refer to Figure 4.11, the temperature is lower on channel 1 for every minute up to 60 minutes to the left. But in minute 60, the temperature in the three channel matching.

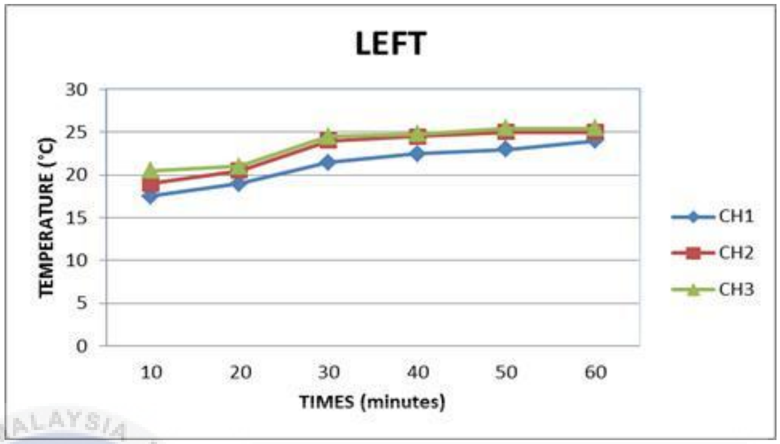


Figure 4.11 : Temperature by times for left using water, ice and salt

Figure 4.12 can be seen at the right temperature of water added to the ice and salt is not very significant changes between the three channels. But there are changes in temperature ranging from 10 minutes to 60 minutes for each channel.

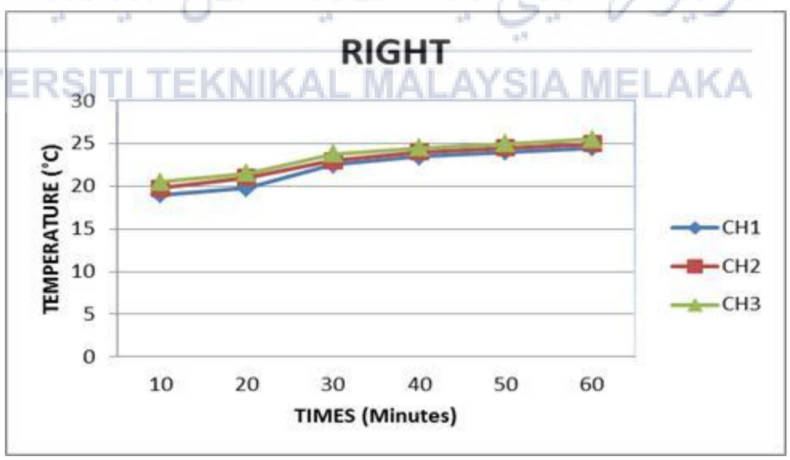


Figure 4.12 : Temperature by times for right using water, ice and salt

4.2.2 Analysis of Temperature by channel

Base on the Figure 4.13, 4.14 and 4.15 can be seen that the temperature on channel 1 lower then channel 2 and 3. Temperature changes in the three channels for the case that only use of water is not very significant amendments, because the water temperature in the container is nearly equal to room temperature used in the course of the experiment. However, a significant change can be seen in all three channels when ice and salt used. This is because, in the container temperature lower than room temperature. However, a significant change is on channel 1 because channel 1 position closer to the cooling coil than the channel 2 and 3. Although the temperature at the channel 1 lowest then channel 2 and 3, but to achieve thermal comfort in Malaysia, channel 2 and 3 much better because the range of temperature of this channel is between 23° C to 26°C.

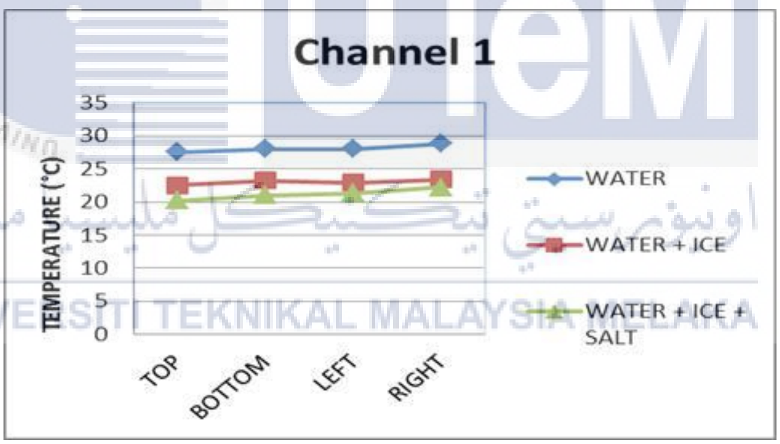


Figure 4.13 : Average Temperature for Channel 1

Figure 4.14 shows the average temperature for channel 2 for the three cases and on the top, bottom, left and right. Can be seen temperature for the case of water ice and salt plus a lower temperature than others. While the highest was in the case of using water only.

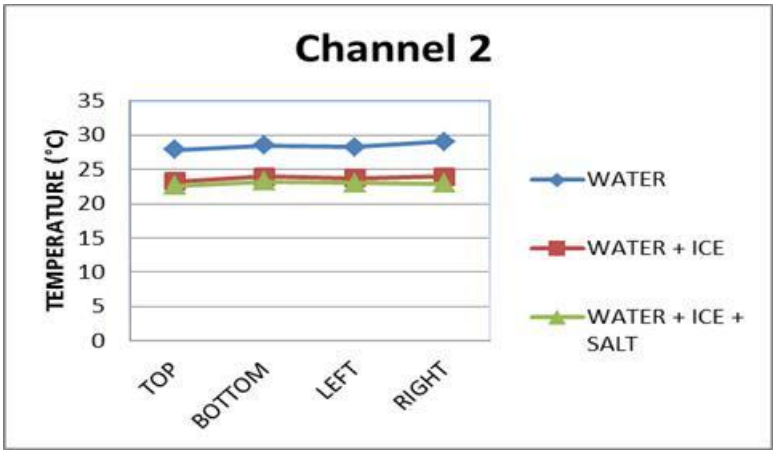


Figure 4.14 : Average Temperature for channel 2

Figure 4.15 is based on average temperature for channel 3 looks the same as the right channel 2. However, a higher temperature than other parts.

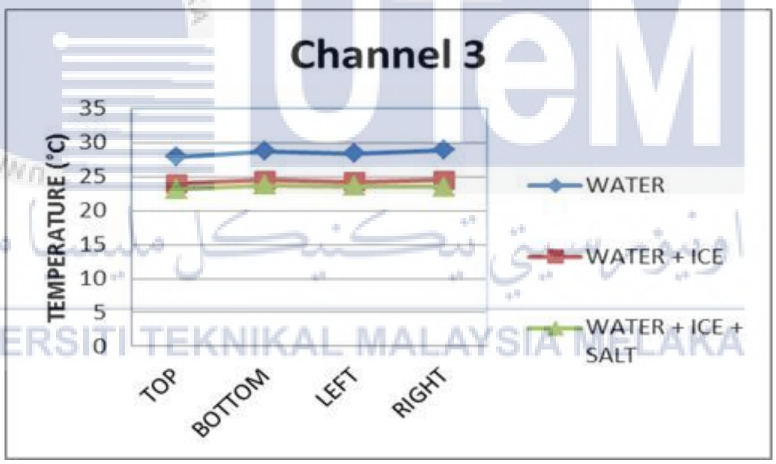


Figure 4.15 : Average Temperature for channel 3

4.3 Analysis average of Air flow rate and Air Velocity

Table 4.3 shows the experimental data obtained for the air flow rate and air velocity for each channel. purpose data water flow rate and water velocity is taken to determine the velocity of the wind up on each channel according to the comfort .

Table 4.3 : Air flow rate and Air velocity

	TOP			BOTTOM			RIGHT			LEFT		
	CH 1	CH2	CH 3	CH1	CH 2	CH 3	CH 1	CH2	CH3	CH 1	CH 2	CH 3
CFM	882.02	796.02	626.28	603.53	659.05	554.76	714.06	713.88	754.99	777.82	700.72	697.57
	898.12	782.52	685.92	643.33	639.29	601.88	781.75	749.18	740.05	777.66	739.26	696.26
	888	789.42	719.04	643.93	582.76	659.05	764.52	765.21	734.53	690.03	765.56	665.21
AVERAGE	889.38	789.32	677.08	630.26	627.03	605.23	753.44	742.76	743.19	748.50	735.18	686.35
VELOCITY (m/s)	4.48	4.03	3.18	3.15	3.45	2.66	3.61	3.63	3.82	3.84	3.52	3.62
	4.57	3.96	3.53	3.29	3.16	3.22	3.93	3.9	3.76	3.65	3.76	3.5
	4.51	4.1	3.66	3.26	2.92	3.29	3.88	3.91	3.68	3.5	3.89	3.32
AVERAGE	4.52	4.03	3.46	3.23	3.18	3.06	3.81	3.81	3.75	3.66	3.72	3.48

According to figure 4.16 it can be concluded that the amount of air flow rate at the top of the resulting higher for all three channels and the lowest CFM is to the bottom. Air flow rate to the top of the high value 889.38cfm to channel 1, 789.32cfm to channel 2 and channel 3. 677.08cfm for here we can see that the positions of different channel will produce different air flow rate. Channel position closer to the fan and cooling coil, the higher the CFM produced, and the greater the distance channel with the fan and cooling coil itinerant CFM resulting value.

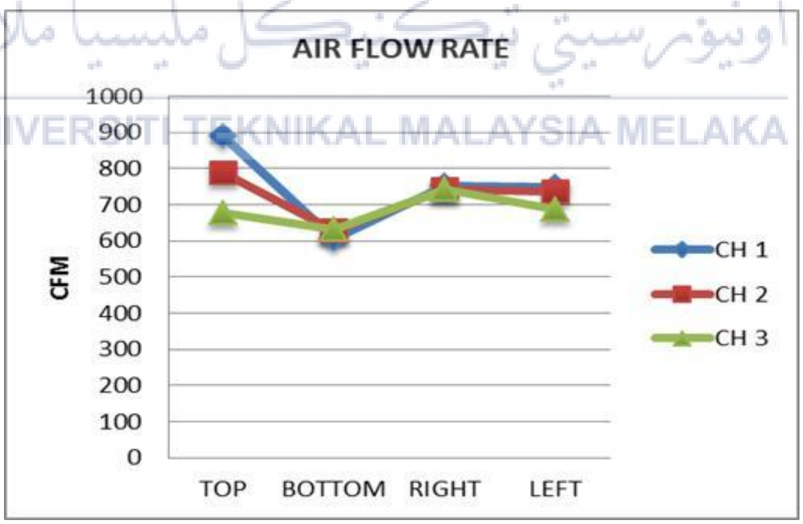


Figure 4.16 : Average of Air Flow Rate

Based on the experiment conducted, Figure 4.17 shows the average air velocity taken during the experiment. Here we can see that the velocity of the air at the top of each channel is higher than the bottom, right and left. However, there is still the resulting reduction in channel 2 and channel 3 then channel 1. This is because the distance between channels 2 and 3 further from the fan and cooling coil than on channel 1. The resulting wind velocity of channel 1 is 4.52 m/s , while the channel 2 is at 4.03 m/s, is a reduction of 10.84% from channel 1. Next, the air velocity of channel 3 is 3.46 m/s, is a 23.45% decrease compared to channel 1. From previous study, the recommended velocity supply in theatres application is 4.1 m/s to 5.1 m/s. Therefore from the data experiment for air velocity suitable to apply for theatres room.

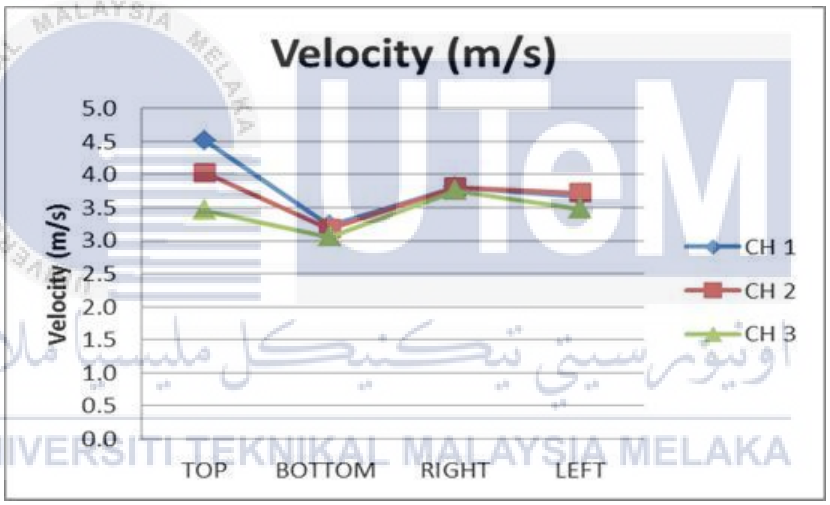


Figure 4.17 : Average of Air velocity

4.4 Average Temperature

Average temperature analysis was based on the analysis of average temperature for three case and for all case.

Table 4.4 : Description of the experimental measurement cases.

CASE 1	water
CASE 2	Water and ice
CASE 3	Water, ice and salt

4.4.1 Average temperature for three case

Table 4.5 shows the average of temperature for water, water and ice, and water, ice and salt on channel 1, 2 and 3.

Table 4.5 : Average of temperature for Water, Water and Ice and Water, Ice and Salt

CHANNEL	LOCATION	TEMPERATURE (°C)		
		WATER	WATER + ICE	WATER + ICE + SALT
1	TOP	27.5	22.5	20.2
	BOTTOM	28	23.2	21
	LEFT	28	22.9	21.3
	RIGHT	28.8	23.4	22.2
2	TOP	27.8	23.3	22.6
	BOTTOM	28.5	23.9	23.2
	LEFT	28.2	23.7	23
	RIGHT	29	23.9	22.9
3	TOP	28	24	23.2
	BOTTOM	28.8	24.5	23.8
	LEFT	28.5	24.3	23.6
	RIGHT	29	24.5	23.5

According to figures 4.18, 4.19 and 4.20 can be seen that the temperature change in case one is not too significant for each channel. This is because the temperature in the container is nearly equal to room temperature. While, for case 2 and 3, the temperature change can be seen on every channel because the temperature in the container lower than room temperature. Therefore, the temperature in the channel change due to the distance between the channel and the cooling coil. In this case it can be seen that the channel 1 produces a lower temperature than channel 2 and 3.

Figure 4.18 shows the average water temperature of the top, bottom, right and left three weeks for the channel.

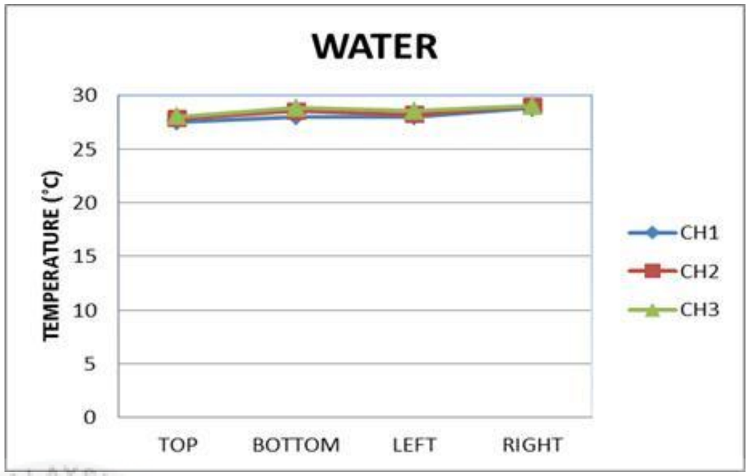


Figure 4.18 : Average Temperature for water

Refer to Figure 4.19, the temperature on channel 1 is lower for all parts and the highest on channel 3, for the case of the use of water and ice.

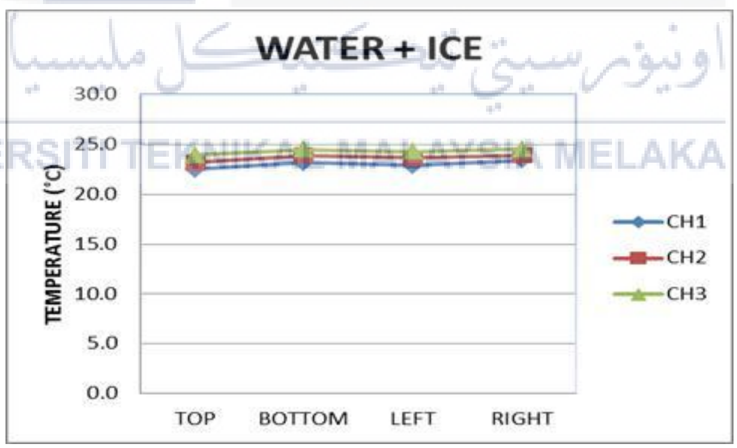


Figure 4.19 : Average temperature for water and ice

Figure 4.20 represents the temperature of water added to the case of ice and salt. The temperature at the lowest channel 1 for each section, and the highest is on channel 3.

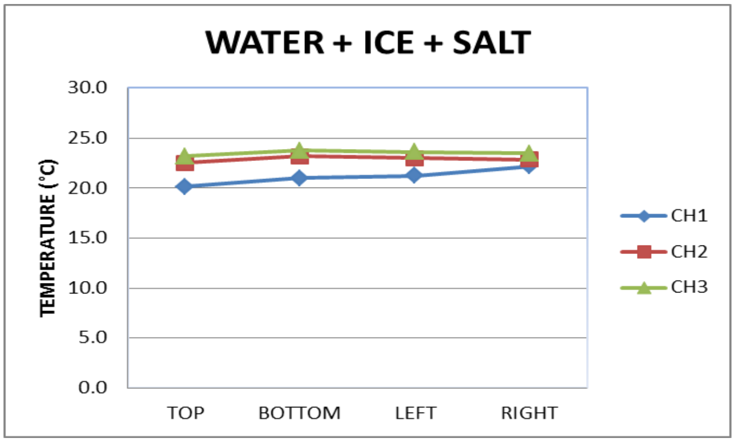


Figure 4.20 : Average temperature for water, ice and salt

4.4.2 Average temperature for all case

As illustrated in Figure 4.21, the average temperature change for all three cases the measurement experiment. refers to cases 2 and 3, the temperature drop significantly as compared to the case 1. This is so because, the lowest temperature worksheets are at the top of each case and on channel 1. The temperature will rise on channel 2 and 3 due to a channel with a cooling coil.

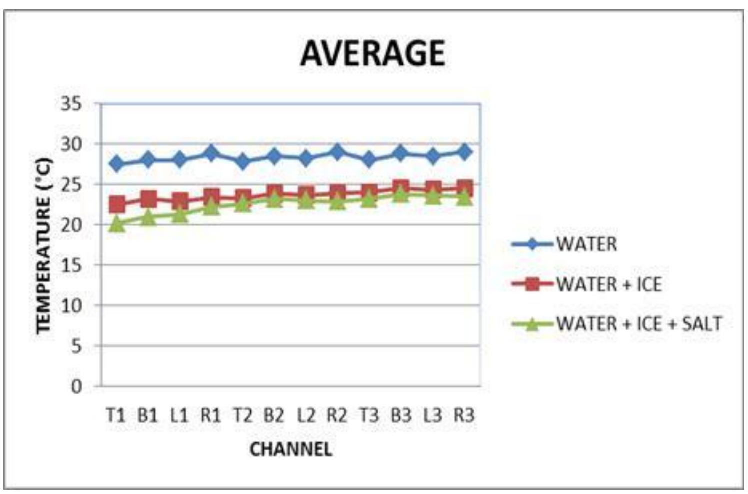


Figure 4.21 : Average temperature for all case

CHAPTER 5

CONCLUSION

5.0 Introduction

This chapter discusses about the conclusion and some suggestions for future work to further improve the development of the system. It also stresses the significance and potential application from the research output.

5.1 Summary of project

Based on this project, this thesis presents the use of hydronic cooling system for temperature suitability to achieve thermal comfort in Malaysia, depending on channel position and orientation. This is evidenced by research on the prototype and the analysis of data.

5.2 Achievement of Research Objectives

Upon completion of this project, it can be seen that the use of a hydronic cooling system able to generate low temperature. But to determine the selection of the appropriate orientation for this research is very complicated because according to studies that have been conducted, the channel at the top is lower than the bottom temperature.

This is so because, after studied the cause, the gap between the floor and ducting not enough for air circulation. However, the temperature on channel 1 for each orientation is still low compared with other channel. This is because channel 1 is closer to the cooling coil. So that, the temperature in the channel 1 low then channel 2 and 3. According to the data obtained, to achieve thermal comfort in Malaysia, the temperature on channel 2 and 3 better then channel 1 as being in the range of 23°C to 26°C.

5.3 Significance of Project

The significance of this study is to determine whether the use of hydronic cooling system is able to produce a suitable temperature to achieve thermal comfort in Malaysia. it aims to compare whether the system is able to produce better temperature than existing systems on AHU now.

5.4 Problems Faced During Project

Although this system successfully reaches the required temperature, there occur problems in completing this project. One of them is the limited time and need to focus on the progress of the current study. The place, time and the weather was also a problem for me to get the right temperature. In addition, the use of laboratory time is so short and not flexible, it is difficult for me to prepare prototype in my spare time because sometimes the schedule does not match with the lab together.

5.5 Suggestion for Future Work (Recommendation)

This part of the report is important because it is based on the observation to improve and upgrade the system for the better in the future. The system can be upgraded to make improvements at the foot of the prototype. Legs can be raised to create adequate gap for air circulation. In addition, studies on the shape and size of the channel can also be in place to minimize heat loss. In addition, the best materials more suitable as coil can be used as a pipe connector from the container to the cooling coil. By reason of the coil is the most important factor in archive heating and cooling efficiencies. Lastly, the system must be better and more interesting to use in order to achieve the level of thermal comfort.

APPENDICES

Appendix A: Cleaning process

Appendix B: Cutting process

Appendix C: Running project for data collection

APPENDIX A1

APPENDIX A2

APPENDIX B1

APPENDIX B2

APPENDIX B3

APPENDIX C1

APPENDIX C2

REFERENCES

A.S. Binghooth, Z.A. Zainal, 2012. Performance of desiccant dehumidification with hydronic radiant cooling system in hot humid climates. *Energy and Buildings*, 51 (2012), P. 1–5.

Fontanini, A., Olsen, M. G., & Ganapathysubramanian, B. (2011). Thermal comparison between ceiling diffusers and fabric ductwork diffusers for green buildings. *Energy and Buildings*, *43*(11), 2973–2987. http://doi.org/10.1016/j.enbuild.2011.07.005

Fan Engineering FE-2300. Twin City Fan Companies, Ltd (2000) p. 1-4

Fan and Blowers, Bureau of Energy Efficiency Companies, p. 93-112

Geethu Priya, and Nagaraju Kaja, 2016. Significance of air movement for thermal comfort in educational buildings, case study of a classroom. International Advanced Research Journal in Science, Engineering and Technology, 3 (2016), p. 88-93

Hamdan b.Ali, Shawaludin md.Aris, and Mat Misiah Ayob, (1989). Teknologi Penyejukan dan Penyaman Udara. [Text-book].

Licina, D., & Sekhar, C. (2012). Energy and water conservation from air handling unit condensate in hot and humid climates. *Energy and Buildings*, *45*, 257–263. http://doi.org/10.1016/j.enbuild.2011.11.016

Schiavon, S., Lee, K. H., Bauman, F., & Webster, T. (2011). Simplified calculation method for design cooling loads in underfloor air distribution (UFAD) systems. *Energy and Buildings*, *43*(2-3), 517–528. http://doi.org/10.1016/j.enbuild.2010.10.017

Xia, L., Chan, M. Y., Deng, S. M., & Xu, X. G. (2010). Analytical solutions for evaluating the thermal performances of wet air cooling coils under both unit and non-unit Lewis Factors. *Energy Conversion and Management*, *51*(10), 2079–2086. http://doi.org/10.1016/j.enconman.2010.02.041

X.J. Zhanga, C.Y. Yua, S. Lia, Y.M. Zhengb, F. Xiaoc, 2011. A museum storeroom air-conditioning system employing the temperature and humidity independent control device in the cooling coil. Applied Thermal Engineering 31, (2011), P. 3653–3657